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THE

JOURNAL OF GEOLOGY

JANUARY—FEBRUARY 1900

SUGGESTIONS REGARDING THE CLASSIFICATION OF THE IGNEOUS ROCKS

It may well be doubted if there is any science which presents greater difficulties to the teacher than that of systematic petrology—the classification of rocks. Even the name itself is seldom used, and appeals to the petrologist as almost a misnomer, because the science is so lacking in system, or, shall we say, overburdened by "systems." The German petrologists, under the leadership of Rosenbusch and Zirkel, and the French with Michel-Lévy at their head, are committed to the partial use of "systems" which are regarded as obsolete by their colleagues in other lands. The English and American schools of petrology have each their "systems" which differ from the German "systems" and more or less from each other. Yet as all are using essentially the same language of terms, the confusion which has arisen is so great that it is now necessary in employing a rock name to state at length what meaning the word is intended to convey.

Such a state of affairs is explainable on two grounds: first, the hesitancy felt in departing from the views held by the fathers of the science, and, second, the inherent difficulties which lie in the science itself, due to the complex nature of rocks.

The modern petrographical microscope, with its accessories, has introduced great refinement into the methods of study, so that descriptive petrology, or petrography, has become a very exact science. It is now possible to describe a rock in so many ways (in respect to so many of its attributes, such as mode of occurrence, texture, mineral composition, chemical composition, alterations, genesis, etc.,) that the difficulties in the way of bringing the results of the study into an orderly classification have been greatly increased. Nor is there reason to hope for any immediate remedy for this condition, since the largest and most representative body of petrologists ever assembled — the Seventh International Congress of Geologists, at St. Petersburg — was almost unanimous in the conviction that it would be useless to attempt to harmonize the nomenclature of the science by any early action of that body. The view was, however, expressed that something might be accomplished through the labors of a representative committee, which should, by frequent and careful deliberations, arrive at a tentative scheme for presentation to a future congress.

Undoubtedly the greatest obstacle in the way of reaching an understanding in the matter is that different values are assigned by different petrologists to the same attribute in rock classification. Some would lay greatest stress upon the mode of occurrence in the field; others would give the first place to mineral constitution, still others to texture, chemical composition, etc.

THE FIELD GEOLOGIST VS. THE PETROLOGIST

In deciding what shall be given first place as a basis in any system of rock classification, it should be realized, it seems to me, that the igneous rocks are not the sole property of the petrographer. The field geologist or the "naturalist," whatever be his special line of work, has need to make determination of igneous rocks, and he has a right to ask of the petrographer, who from his greater familiarity with rocks is charged with arranging them in an orderly system, such a classification that the geologist's determination in the field shall be *incomplete* rather than *incorrect.* It should be made possible for the geologist to determine correctly at least the family to which a rock belongs, leaving to the petrographer the determination of rock species as well as the solution of the purely petrological problems.

To aid his eye the field geologist has only his pocket lens, and whatever rock species are fixed upon by petrologists they should be grouped into a comparatively small number of families, limited by simple and easily tested characteristics. In the case of the volcanic rocks it would be necessary to adopt terms broad enough to cover all rock types which it is found impossible to easily distinguish in the field. This reform would be made in the interest of the petrographer quite as much as of the geologist. If this be done the petrologist may multiply terms as he will to express any extension of his refined methods of study without in any way disturbing the composure or the effective work of the great body of field geologists.

BEARING OF RECENT PETROGRAPHICAL STUDIES ON ROCK CLASSIFICATION

From the point of view of the systematic petrologist the two most significant developments of petrology during the closing years of the nineteenth century have been, first, the numerous observations showing that the time honored families of igneous rocks, once supposed to be more or less sharply delimited, pass by insensible gradations into one another; and second, the return of chemical composition as a basis of rock classification to a position of prominence nearer to that which it formerly occupied.

The attention of petrologists was first drawn to the marked facial differentiation of a rock magma when the late Professor George H. Williams showed that rocks as diverse as quartz-mica-diorite and peridotite occur in the same stock near Peekskill, N. Y.[1] Since that time other investigators, but notably Iddings, Brögger, Ramsay, and Weed and Pirsson, have multiplied the observations of other but similar cases of magmatic differentiation. It is now the exception rather than the rule to discover an igneous rock mass of considerable dimensions in which some evidence of such gradations may not be observed.

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[1] G. H. WILLIAMS, The Gabbros and Diorites of the "Cortlandt Series," on the Hudson River near Peekskill, N. Y. Am. Jour. Sci. (3) XXXV, pp. 438–448, 1888.

The introduction of the petrographical microscope and its accessories, bringing as it did quick and delicate methods for determining the mineral constitution of a rock, naturally enough drew away the attention of petrographers from the slower and less brilliant methods of chemical analysis, which up to that time had been almost the only ones in use. Moreover most of the analyses of the period were, as we now know, inaccurate and failed to show the real chemical differences between individual rocks. The multiplication of the number of analyses and the improvements in the methods of rock analysis which have been made during the last decade, particularly by Hillebrand, have disclosed important differences among rocks formerly classed together, and thus necessitated a considerable elaboration of the systems of classification.

With this elaboration rock names have been introduced into the science with a rapidity which is little short of bewildering. The older petrological nomenclature was largely binomial or polynomial (*i. e.*, mica-syenite, quartz-mica-diorite) though the recent names seem planned for a monomial nomenclature (*i. e.*, ciminite). It is therefore not strange that misunderstanding has arisen in some quarters, where it is not realized that the new names proposed are for the most part specific and varietal in their nature and in no way to be correlated with the great family names such as granite or gabbro, and hence a protest has been made against what seems a needless overburdening of the science with names. Without entering upon this question here it may, I think, be stated with all assurance that some reforms are imperatively demanded before the worker will be fully equipped to discover the relationships among rocks because of the incubus of unclassified facts by which the science is now encumbered. Some of the particular reforms which to me seem desirable and practicable will be briefly described.

The definition of a rock as an object rather than as an integral part of the earth's crust.—The Wernerian conception of a rock as a geological unit or integral part of the earth's crust, still held by German petrologists, was adequate enough so long as rock masses were regarded as essentially homogeneous. With the discovery that such masses are usually quite heterogeneous and frequently represent not only several rock species but sometimes include almost the whole gamut of rock families, it became necessary to adopt some other definition. No other course seems open under these circumstances than to consider the individual rock specimen as the unit of classification and describe it primarily as an object, as is done with the units in the systems of other sciences.[1] If this is done it should be possible to *name* a rock from study of the specimen only though the *full description* would involve no less of field study than is undertaken when rocks are classified on the basis of their geological occurrence.

The importance of texture as a basis of classification.—All systems of classification of the igneous rocks emphasize more or less strongly rock texture as a basis of classification, for the reason that the texture is one of the properties of a rock most easily examined; and, further, because it is dependent so largely upon the peculiar conditions of rock consolidation or subsequent metamorphism. If rocks are described as objects this property of texture becomes inevitably of the very first importance.

The two main groups of the igneous rocks which are now generally recognized as distinguishable on the basis of texture are: first, those having a texture designated by Rosenbusch as *hypidiomorphic granular*, but which may in simpler language be referred to as *granitic*, the essential characteristic of which is that the mineral constituents by their manner of interlocking indicate for the rock in which they occur practically an uninterrupted period of crystallization; and, second, the *porphyritic* texture in which the occurrence of two or more generations of the same constituent mineral indicates that the process of consolidation was not a continuous one but consisted of two or more stages.

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[1] Cf. WHITMAN CROSS, The Geological *vs.* the Petrological Classification of Igneous Rocks. JOURN. GEOL. VI, p. 79, 1898. See also TEALL, British Petrography, p. 65.

The time honored but now obsolescent classification of igneous rocks on the basis of geological age has left us as a legacy a double nomenclature for the rocks of porphyritic texture, and this may be well illustrated by the terms "quartz porphyry" and "rhyolite" applied to rocks of porphyritic texture having a chemical composition similar to the granites. The former in its traditional, and also in its present German signification, refers to rocks of pre-Tertiary age, the latter to Tertiary or later rocks. The tendency of American petrographers seems to be to abandon entirely terms of the class of "quartz porphyry" and to extend the terms correlated with "rhyolite" to cover the rocks which were previously included in both groups. This tendency seems to me to be an unfortunate one since it results in classing together rocks which are essentially unlike. There may be no important difference between a particular "quartz porphyry" and a particular "rhyolite," but compare a drawer of hand specimens of the former with one of the latter and argument is unnecessary to show that as classes they are essentially different. The "quartz porphyries" are, as a class, devoid of vesicular and fluxion structures—they are in their mode of occurrence hypabyssal—and they more generally show the effects of devitrification, weathering, etc.

The "rhyolite" class of rocks may be conveniently distinguished from the "quartz porphyry" class by the possession of either vesicular or rhyolitic (fluxion) textures. Correspondence with some representative American petrographers has indicated to me that a restriction of the terms, rhyolite, trachyte, andesite, basalt, etc., to describe porphyritic types possessed of rhyolite or vesicular textures, would meet with considerable favor. Though of these terms rhyolite alone in its derivation calls attention to a fluxion texture, the others by their usage (trachytic structure, andesitic structure, etc.) have been given the same significance. The terms, rhyolite-porphyry, trachyte-porphyry, andesite-porphyry, etc., by their substitution for the objectionable names, quartz-porphyry, quartzless porphyry, etc., would carry with them the idea of varietal rather than specific variation from the family type, and would, moreover, obviate the danger of their being interpreted in terms of the age classification.

Combination of chemical and mineralogical composition as a basis for rock classification.— Probably the majority of those petrologists who define rocks as objects would agree that chemical and mineralogical composition with texture should occupy the foremost places in rock classification.[1] It would probably be more satisfactory, were it practicable, to adopt chemical composition divorced from mineral composition as the primary basis in classification, but we are, per force, compelled to look first to the mineral composition, and work backward from this to the chemical composition — the chief factor in determining mineral composition. In the past the mineralogical examination of rocks has been largely qualitative, resulting, in some cases, in the classing together of rocks strikingly different as regards their ultimate chemical composition, but a stage has now been reached where such a method is no longer adequate. Pirsson has called attention to the necessity of paying greater regard to the relative quantities of the several essential constituents of a rock, thus making a rough estimation of its ultimate chemical composition.[2]

Specific, generic, and family rock names are applied to arbitrary rock types separated from one another by no sharp lines.— It follows, from the gradations generally observed to connect the families of the igneous rocks, that the names which we adopt to designate any individual rock, or class of rocks, is applied as a *type* name in the sense that it applies to a particular rock or collection of related rocks, descriptions of which have been placed on record. The lines separating the several types are fixed arbitrarily, and would, in general, be located somewhat differently if undertaken at the outset by different individuals. For the types of larger order, these lines have been fixed by the traditional rock groups, and they are not likely to be much changed, but for the new and specific types they will be largely determined by the particular rock areas which are first examined.

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[1] Cf. TEALL: British Petrography, p. 69; WHITMAN CROSS: loc. cit., p. 80; J. P. IDDINGS: On Rock Classification, JOUR. GEOL., 1898, VI, p. 93; F. ZIRKEL: Lehrbuch der Petrographie, I, p. 829, 1893; W. C. BRÖGGER: Die Gesteine der Grorudit-Tinguait Serie, Christiania, 1894, p. 92.

[2] Igneous Rocks of Yogo Peak, Montana, Am. Jour Sci. (3) L, p. 478.

A much more general use of intermediate family type names is inevitable, and terms like grano-diorite (or better, granito-diorite), trachy-andesite, etc., should be utilized.[1]

Rock relationships should be indicated by the combination of names into a binominal, or, if necessary, polynominal nomenclature.—The multiplication of specific terms, whose derivation has only a geographical signification (*e. g.*, Toscanite, Absarokite, Litchfieldite), furnishing not the slightest indication of the rock's relationships, is fast bringing petrologists to the condition of the Chinaman who is required to learn a unique syllable for every word in his language. Not possessing the admirable memory training of the Chinaman, the petrographer finds himself somewhat bewildered under the rain of new petrographical names which has characterized the closing years of the century. Many of these terms have been rendered necessary by the elaboration of the system of classification, due to the improved methods of chemical examination, and to the discovery of new petrographical provinces, and others are sure to be needed, but the enterprise in this branch of the science manifested in some quarters has sometimes provided us with two, or even three, names for the same specific rock type.

There can be no question that the nomenclature of petrography can be greatly simplified by a return to a binomial or polynomial nomenclature, which, fortunately, can be accomplished without much confusion, provided the old names of rock families be retained, together with compound names for the gradational types connecting them. An illustration may be furnished by the interesting types, Toscanite, Vulsinite, and Ciminite, recently described by Washington.[1] They form together an intermediate family connecting the trachytes with the andesites, and called by Washington, trachy-dolerite, though it seems to me trachy-andesite is to be preferred. Trachy-dolerite-ciminite, or trachy-andesite-ciminite, is a term which tells at once that the rock to which it applies is a species of trachy-andesite which has been described from Monte Cimino. The term latite proposed by Ransome[2] for this group, while otherwise appropriate, fails to show the family relationships. Van Hise[3] has already suggested such a compounding of terms to express relationships. Certainly if the nomenclature of the science is to aid rather than to distract the worker some such reform from present conditions is demanded.

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[1] Cf. BRÖGGER : op. cit., p. 93.

Graphical methods essential to a comprehensive study of rock analyses.—The necessity for studying the chemical composition in connection with the mineral composition of a rock requires that we examine in connection with one another the chemical analyses of all rocks having the same mineral constituents; or, better, those having the same constituents in the same relative quantities to a rough approximation. Such analyses show variations of one, two, or more per cent. in the quantities of some of the constituents for a single species or variety. But, on the other hand, differences of one or two per cent. in the amount of a constituent may be the cause of important differences in mineral composition or in other characteristics of the rock; hence it is important to know to that degree of precision the amount of each constituent which is present. For each analysis that would be remembered, it is necessary, then, to keep in the mind eight numbers of one or two figures each; and the student of petrology who would be familiar with the chemical nature of any given rock type must know the range in the percentages of the eight principal constituents. Moreover, he is not assisted in this by the knowledge that the upper and lower limits which he learns for a constituent of one species are at the same time, respectively, the lower and the upper limits for the same constituent in other allied species. A tax is thus imposed upon the memory far beyond what it may be reasonably expected to bear, and this tax is increased with the fixing of each new rock species.

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[1] H. S. WASHINGTON: Italian Petrological Sketches, No. 5, JOUR. GEOL., V, pp. 349–377, 1897.

[2] F. LESLIE RANSOME: Some Lava Flows of the Western Slope of the Sierra Nevada, Cal., Am. Jour. Sci. (4), V, p. 373, 1898.

[3] C. R. VAN HISE: The Naming of Rocks, JOUR. GEOL., VII, pp, 691–693, 1899.

The eye assists the mind not only to discover intricate relationships, but also to retain them, whenever the facts can be expressed by a definite form. This has been appreciated especially by the engineering profession, which has been accustomed, by the use of diagrams, to set forth in the most lucid manner facts which only the most laborious methods could otherwise bring out of the tables on which they are based. A curve contains the essence of pages of figures, and is readily carried in the mind owing to the large development of that faculty, which the Germans have so aptly termed *Vorschauungsgabe*. It is noteworthy that so little attempt has been made to apply graphic methods in petrology.

Recently, however, Iddings,[1] Becke,[2] Michel-Lévy[3] and Brögger[4] have each devised diagrams to illustrate rock analyses.

Of these the diagrams of Brögger seem to me the ones best adapted for general use because the simplest and the most characteristic. In the Brögger[5] diagram are set off on radius vectors the amounts of the eight principal chemical constituents reckoned in molecular ratios, ferrous and ferric iron being entered upon the same radius vector, and silica, because so much in excess of the others, being evenly divided between the two horizontal radius vectors. A broken line joining the intercepts on the eight radius vectors forms a polygon, which may be long and narrow, or short and thick, convex above or below, or reëntrant in any portion, left or right handed, etc., according to the chemical constitution of the rock.

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[1] J. P. IDDINGS: The Origin of the Igneous Rocks, Phil. Soc. of Washington. XII, pp. 89–214. Pl. II, 1892; Absarokite-shoshonite-banakite series. JOUR. GEOL., III, pp. 90–97, 1895; On Rock Classification, *ibid.*, VI, p. 92, 1898; Chemical and Mineralogical Relationships in Igneous Rocks, *ibid.*, p. 219.

[2] F. BECKE: Die Gesteine der Columbretes. TSCHERMAK'S min. u. petrog. Mittheil., VI, p. 315. 1897.

[3] M. MICHEL-LÉVY: Porphyr bleu de l'esterel, Bull. de la sèrvice de la carte géol. de la France. Tome IX, No. 57, 1897; Sur une nouveau mode de co-ordination des diagrammes representant les magmas des roches éruptifes. Bull. de la soc. géol. de la France. (3) XXVI, p. 311.

[4] W. C. BRÖGGER: Die Eruptivgesteine des Kristianiagebietes; Das Ganggefolge des Laurdalits. Kristiania, 1898, p. 255. Pl. I.

[5] Or LÉVY-BRÖGGER diagram.

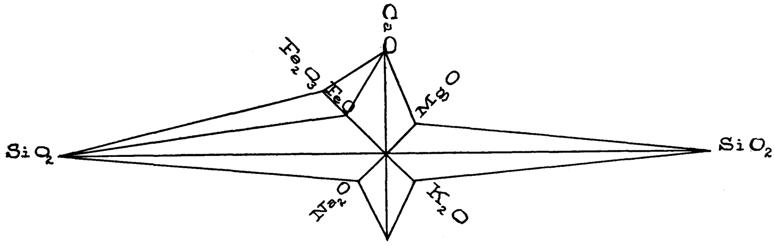


FIG. 1.

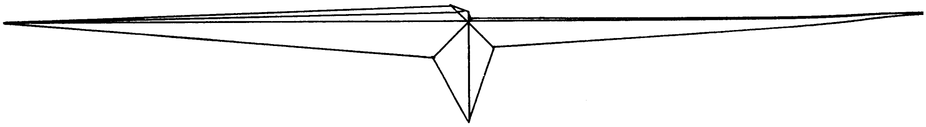
When viewed in this diagram, the rock comes to have a handwriting by which it may be instantly recognized. When drawn to scale, this diagram not only shows the chemical character of the rock but all the results of analysis may be quickly read from it numerically.[1] In it, as in all other successful diagrams the molecular ratio is substituted for the percentage of each constituent. Some authors now publish these ratios with every rock analysis. It is to be hoped that this will soon become a general custom.

THE COMPOSITE ROCK DIAGRAM

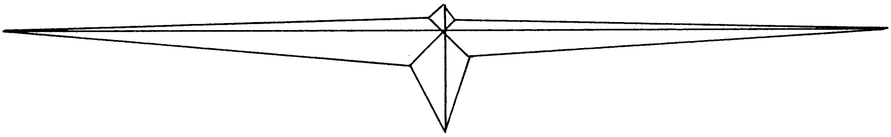
The principal objection to Brögger's diagram is that it represents not a rock species or a rock type but only an individual analysis, the rock type covering a considerable range of differing analyses. So far as I know, only isolated attempts have been made to average rock analyses to secure an adequate conception of the chemical constitution of the rock type, although the method of averaging results is so successfully used in other fields of science.

[1] On plates I, IV, V, and VI, .01 equals 1^{mm}.

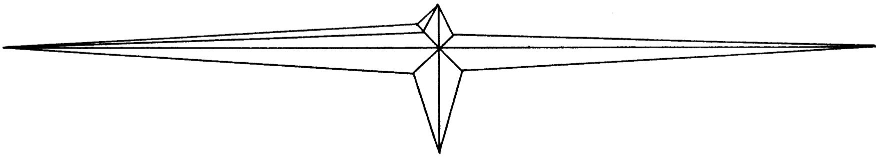
Jour. Geol., Vol. VIII, No. 1 Plate I



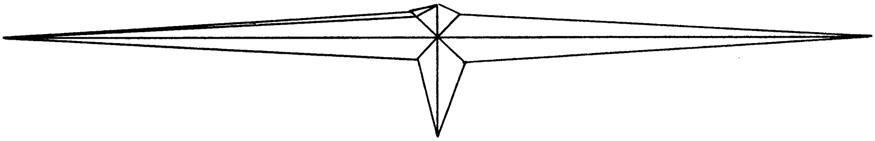
ALKALI GRANITE



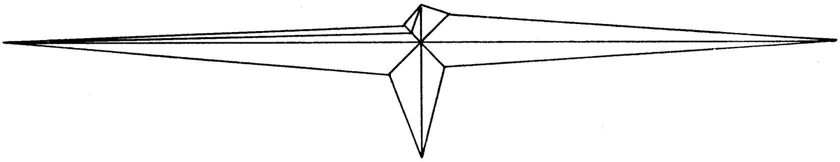
MUSCOVITE-BIOTITE GRANITE



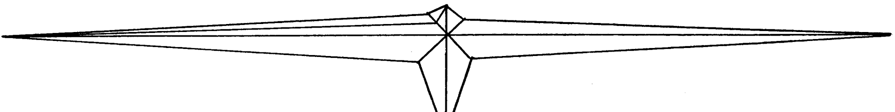
BIOTITE GRANITE



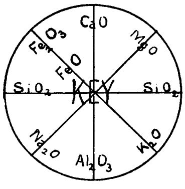
HORNBLENDE GRANITE



AUGITE GRANITE



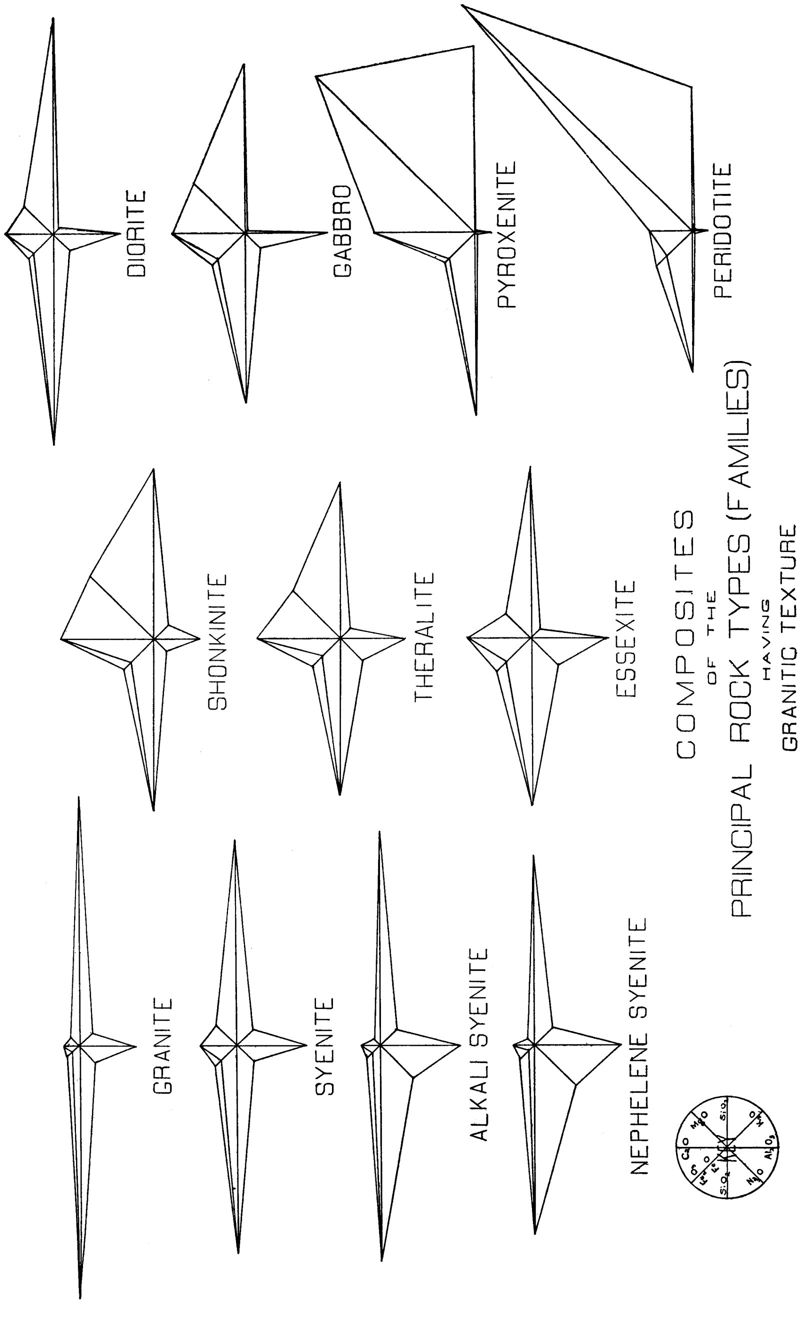
GRANITE



COMPOSITES

In connection with his class in petrology, the writer has for some time made use of diagrams which set forth the average composition of rock types. There are two ways in which such diagrams may be constructed. On the one hand, the diagram may be prepared after the same manner as composite photographs. The Brögger diagrams of a considerable number of representative rocks faintly outlined are superimposed upon the same radius vectors, so as to indicate the range in ratios of each constituent and in the darkest part of the figure the characteristics of the type. A composite diagram, better adapted for general use, because so much less intricate and so much easier to prepare, is obtained by first averaging the molecular ratios of each constituent for the group of analyses, and using the results to prepare a single diagram, which then becomes the diagram of a type instead of that of an individual.

The writer has so far modified the Brögger diagram as to draw the radius vectors so as to make equal angles with one another. The closed polygon obtained by connecting the intercepts on the different radius vectors has a form which changes in a marked degree to correspond with the changes in the length of any radius vector. Since the soda, potash, and alumina are all measured below the horizontal, acid rocks show diagrams stretched out along the horizontal and developed also below the horizontal; while the protoxide bases being all entered above the horizontal basic rocks are short and "fat above." Soda-rich or potash-rich rocks give respectively left-handed and right-handed diagrams, etc. All these facts the eye soon accustoms itself to take in at a glance and subconsciously, as it does in the case of handwriting. It is hardly necessary for the eye to estimate the lengths of the intercepts (a feat it is but poorly qualified to accomplish) for the ratios of the quantities of the constituents to one another is shown by the *angles of slope* of the polygonal sides — something which the eyes easily measures. The larger the number of correct and properly selected analyses which are utilized in obtaining the "composite" of any type, the greater is its value.



COMPOSITES
OF THE
PRINCIPAL ROCK TYPES (FAMILIES)
HAVING
GRANITIC TEXTURE

STUDY OF THE COMPOSITES OF THE PRINCIPAL FAMILY TYPES OF THE IGNEOUS ROCKS HAVING GRANITIC TEXTURE

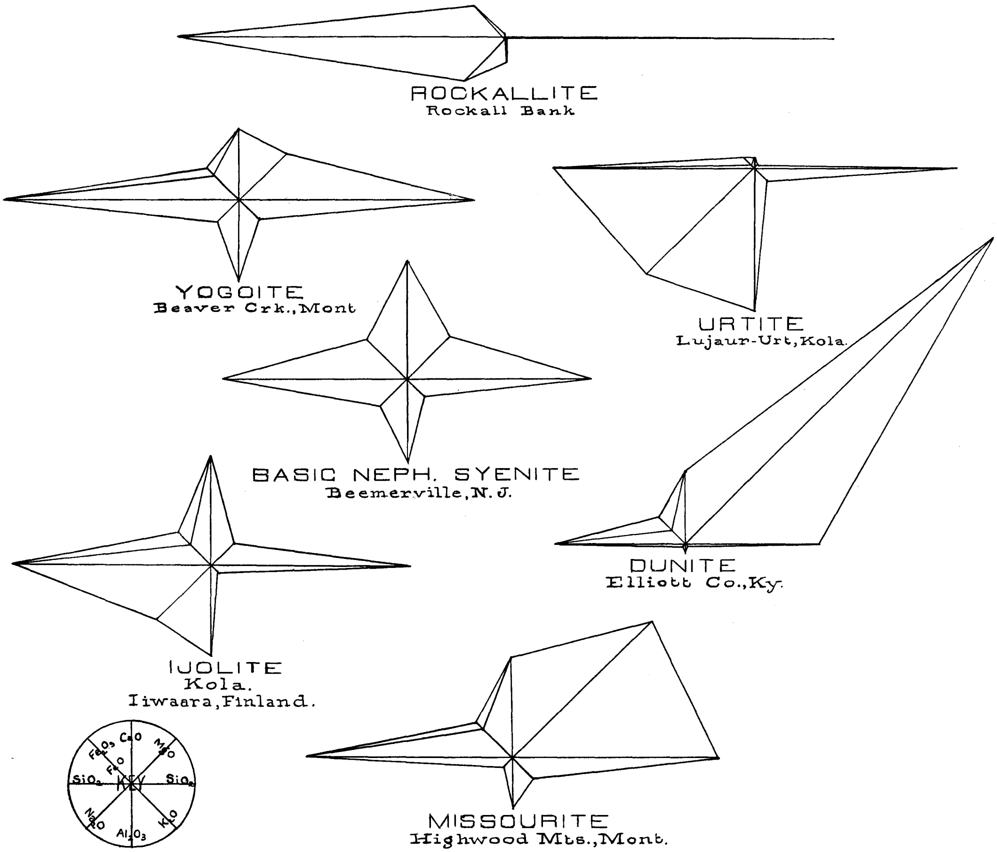
The composite diagram may be made to represent either specific or family types according to the analyses which are combined to produce it. By combining separately analyses of the principal species of granite, viz., alkali-granite, muscovite-biotite-granite, biotite-granite, hornblende-granite, and augite-granite, we are prepared to draw the composite diagram of each and can then compare them with one another ; or, if we choose, we may compose all to form a single composite, which then represents not a specific but a family type—granite. These granite composites may be studied in Plate I. The alkali-granite composite is composed from six analyses, the muscovite-biotite-granite from two, the biotite, hornblende, and augite-granites each from four, so that the family composite is made from the average of twenty analyses.

The composites of each of the families of the igneous rocks having granitic textures may be similarly prepared and studied in connection with one another. (See Plate II). The family types selected, viz., granite, syenite, alkali-syenite, nephelene-syenite, shonkinite, theralite, essexite, diorite, gabbro (including hypersthene-gabbro and norite), pyroxenite, and peridotite, when seen in their composites allow their peculiar characteristics to be read at a glance.

The granites are distinguished from all the other families by their excess of silica and, moreover, by the small quantities of the protoxide bases and moderate amounts of alumina and the alkalies. *The granites, alkali-syenites, and nephelene-syenites form a progressive series which is characterized by decreasing silica and rapidly increasing soda and alumina, and to a less degree by increasing potash and lime, so that the alkali and nephelene-syenite rocks become preëminently the alkali-alumina rocks.*

The shonkonites, theralites, and essexites form a second progressive series in which the silica and iron remain nearly constant but in which the potash, magnesia, and lime steadily decrease as the soda and alumina increase. The essexites are essentially alkali-diorites

Jour. Geol., Vol. VIII, No. 1 Plate III



ROCKALLITE
Rockall Bank

YOGOITE
Beaver Crk., Mont

URTITE
Lujaur-Urt, Kola.

BASIC NEPH. SYENITE
Beemerville, N. J.

DUNITE
Elliott Co., Ky.

IJOLITE
Kola.
Iiwaara, Finland.

MISSOURITE
Highwood Mts., Mont.

SOME RARE ROCK TYPES
(GRANITIC TEXTURE)

distinguished from the diorites by a gain of alkalis, lime and iron, and a loss of silica.

The affinities of the syenites are seen to be entirely with the diorites and gabbros, with which they form a third progressive series which is continued imperfectly in the pyroxenites. In this series, characterized by generally decreasing silica and potash, the magnesia, lime, iron, and alumina increase, soda remaining practically constant throughout. The pyroxenites and peridotites, so poor in alkalis and alumina, show close affinity with each other and with the gabbros.

A few petrographical curiosities are represented in Plate III — rocks so exceptional in their occurrence as to be almost or quite unique. The first of these is Rockallite from Rockall Bank in the northeastern Atlantic,[1] a rock of granitic texture chemically closely related to the pantellerites of Fürstner (see Plate VII); Urtite is a nearly pure nephelene rock from the Kola peninsula[2] in arctic Russia which forms the limiting member of the nephelene-syenite family. Yogoite from Montana[3] is a "basic syenite." The "basic nephelene-syenite" from Beemerville, N. J.,[4] furnishes the most symmetrical of all the diagrams and gives indication of no near relationship to any other specific rock type though it is classed with the nephelene-syenites. The dunite from Elliott county, Kentucky[5] is so low in silica and so high in magnesia as to be very exceptional, though its diagram conforms to the general shape of the peridotite composite. Ijolite[6] and Missourite[7], the two recently

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[1] JOHN W. JUDD: Notes on Rockall Island and Bank (Notice of Memoir) Geol. Mag., Dec., (4), VI, pp. 163–167, 1899.

[2] WILHELM RAMSAY: Urtit, ein basisches Endglied der Augitsyenit-Nephelinsyenit-Serie. Geol. Fören. Stockh. Förh., XVIII, pp. 459–468, 1896.

[3] WEED and PIRSSON: The Bearpaw Mountains of Montana, Am. Jour. Sci., (4), I, p. 357, 1896.

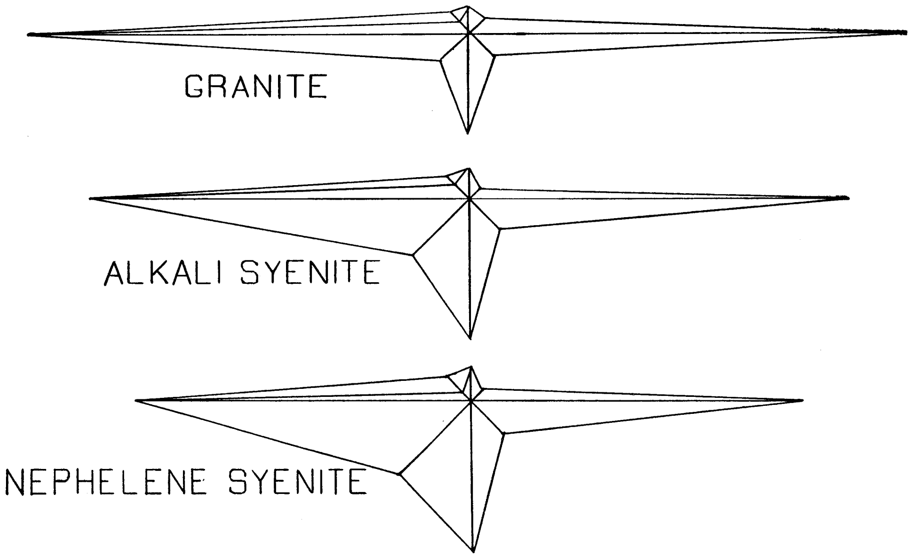
[4] J. F. KEMP: A basic Nephelene-syenite from Beemerville, N. J., N. Y. Acad. of Sci., XI, p. 68, 1892.

[5] J. S. DILLER: The Peridotite of Elliott County, Ky. Bull. No. 38, U. S. Geol. Survey, pp. 1–29, 1887.

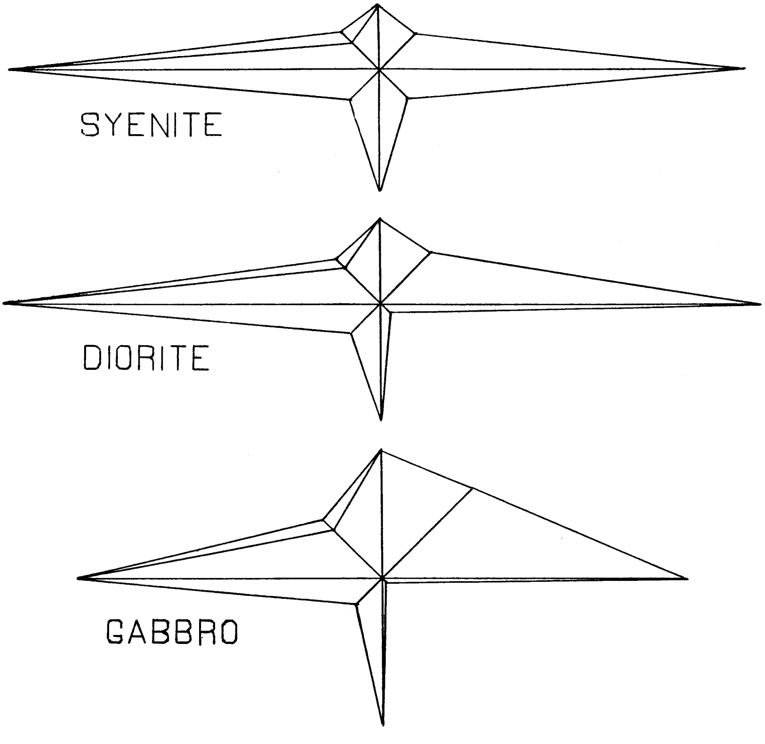
[6] WILHELM RAMSAY: loc. cit.

[7] WEED and PIRSSON: Missourite, a New Leucite Rock from the Highwood Mountains of Montana. Am. Jour. of Sci., (4), II, pp. 315–325, 1896.

JOUR. GEOL., VOL. VIII, NO. 1. Plate IV



GRANITE-NEPH. SYENITE SERIES



SYENITE-GABBRO SERIES

described types for which Rosenbusch has named a new family[1] are certainly remarkable types, but except for the quantities of silica, iron, and lime which they contain, they are as different from one another as two rock types can be imagined to be. Ijolite is rich in soda and alumina, Missourite poor; Ijolite is poor in potash and magnesia, Missourite rich to excess in both. Comparison of their diagrams with those represented in Plate II shows that they are the end members of the Shonkinite-Essexite series, Missourite fitting almost perfectly into the series, being only a trifle low in lime, and Ijolite failing to do so only being too high in lime and a bit too low in iron.

The igneous rocks of granitic texture when examined chemically fall, therefore, quite naturally into three progressive series, which have distinct and common characteristics.—These series may provisionally be designated by the limiting families of each, as the granite nephelene-syenite, missourite-ijolite, and syenite-gabbro series (Plate IV). The peridotites and pyroxenites do not fall perfectly into any of the three, but are yet closely allied to the syenite-gabbro series.

Granite-nephelene-syenite series	Missourite-ijolite series	Syenite-gabbro series
Granite family	Missourite family	Syenite family
Alkali-syenite "	Shonkinite "	Diorite "
Nephelene-syenite "	Theralite "	Gabbro "
	Essexite "	———
	Ijolite "	Pyroxenite family
		Peridotite "

The composite diagrams of the granite-nephelene-syenite and syenite-gabbro series are shown in Plate IV, those of the Missourite-ijolite series in Plate V. The common characteristics of each of the series are well brought out by averaging the composites of the several members in each to form *series composites*, as has been done in Plate VI.

Composites of certain igneous rock types having rhyolitic texture.—No comprehensive attempt has yet been made to determine similar relationships among the rocks of rhyolitic texture, but composites of a considerable number of the specific rock types of

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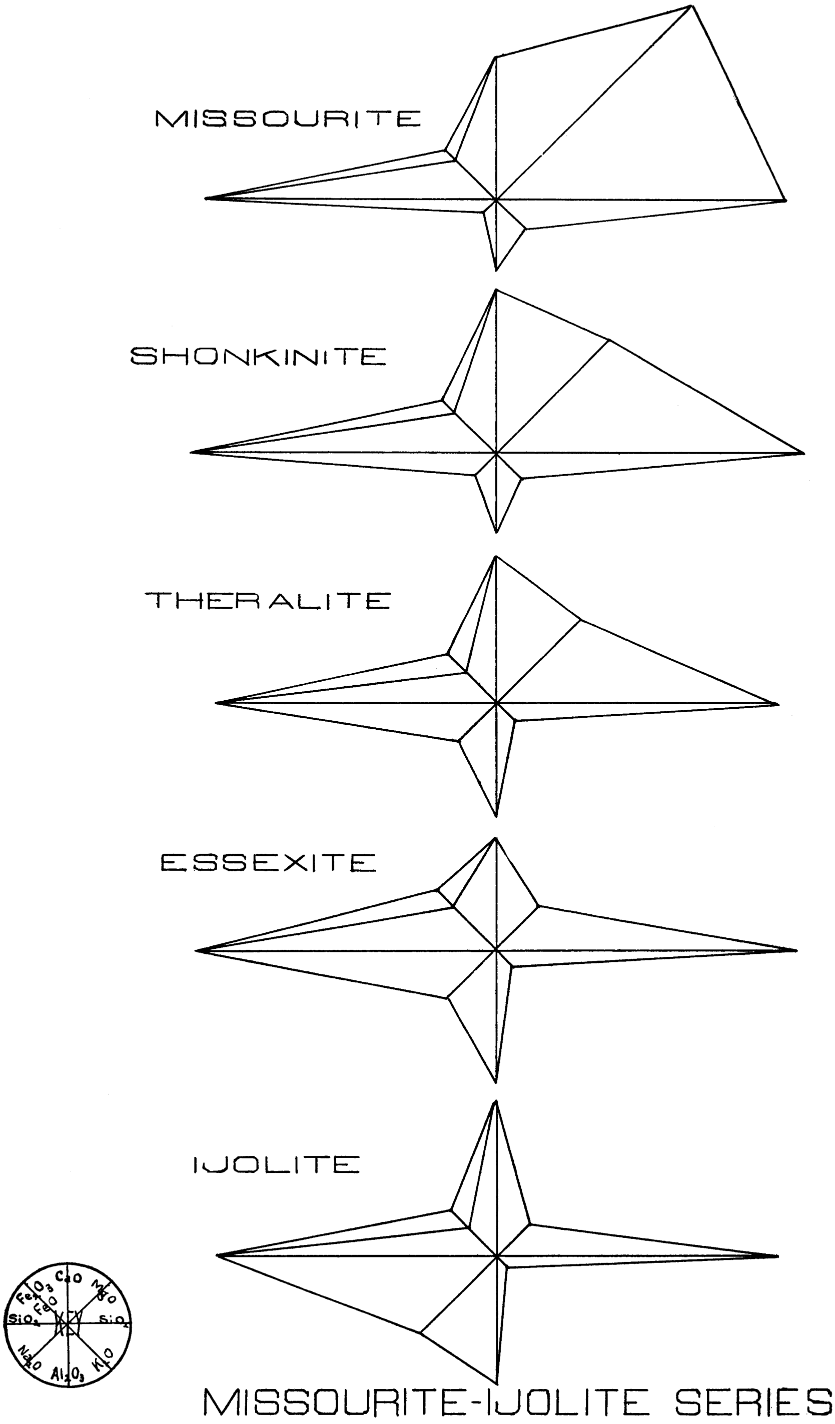
[1] ROSENBUSCH: Elemente der Gesteinslehre, p. 179.

JOUR. GEOL., VOL. VIII, NO. 1 Plate V



MISSOURITE-IJOLITE SERIES

acid and intermediate composition have been prepared. Plate VII displays together the composite diagrams of the specific types belonging to the families which Washington[1] has designated as the trachyte, trachy-andesite, trachy-dolerite, and andesite series.

The rhyolite diagram is a composite of nine analyses of rhyolites from Hungary, Ponza, the Auvergne, Nevada, and Colorado. The soda-rhyolite composite is compounded from six analyses, mainly of Wisconsin rocks soon to be described by C. K. Leith and the writer. The four pantellerites which furnish the pantellerite diagram are from the island of Pantelleria. The trachytes, six in number, are those of the Auvergne, Ischia, the Eifel, the Bohemian Mittelgebirge, and Monte Amiata; and the two domites were from the Auvergne. The vulcanite diagram is not a composite but an individual rock diagram made from the type analysis from Vulcano. The six dacite analyses composed were of rocks from Columbia, Guatemala, Lassen's Peak, Cal., and McClellan Peak, Nev., while the seven andesite analyses used in preparing the andesite composite were of mica- and hornblende-andesites from the Eureka district, Nev.; Custer county, Col.; Cartagena, Spain; the Siebengebirge on the Rhine; Panama; and Columbia. The Toscanite, Vulsinite, and Ciminite analyses are the Italian ones given by Washington,[2] and were respectively ten, ten, and eleven in number. The Banakites, Shoshonites, and Absarokites represented in the analyses are those described by Iddings[3] from the Yellowstone National Park and numbered four, five, and five respectively.

These *specific* composites are much less interesting as indicating relationships than the composites of a higher order would be, but they are here introduced to show that the composite diagram is capable of bringing out the chemical characteristics of rocks which differ only slightly from one another, as well as the characteristics of different families.

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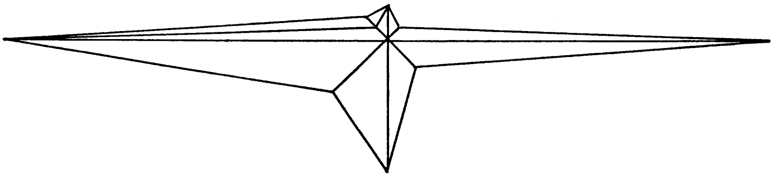
[1] H. S. WASHINGTON: Italian Petrological Sketches, V. JOUR. GEOL., V, p. 366. 1897.

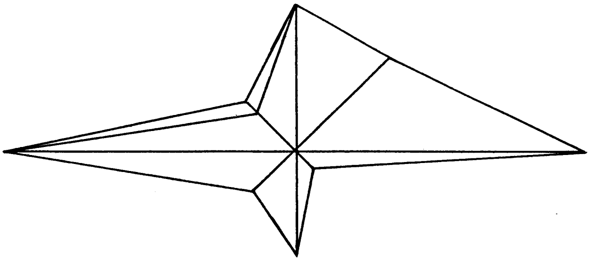
[2] H. S. WASHINGTON: loc. cit.

[3] J. P. IDDINGS: Absarokite-Shoshonite-Banakite series, JOUR. GEOL., III, pp. 935–959, 1895.

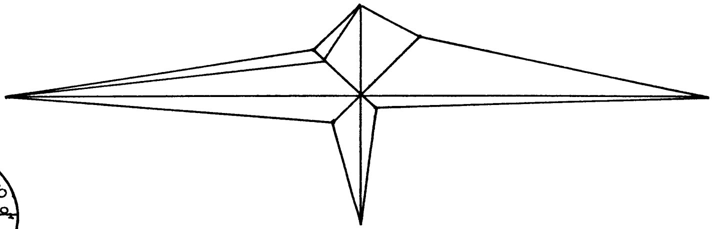
Jour. Geol., Vol. VIII, No. 1 Plate VI

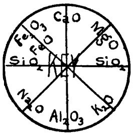


GRANITE-NEPH. SYENITE SERIES



MISSOURITE-IJOLITE SERIES

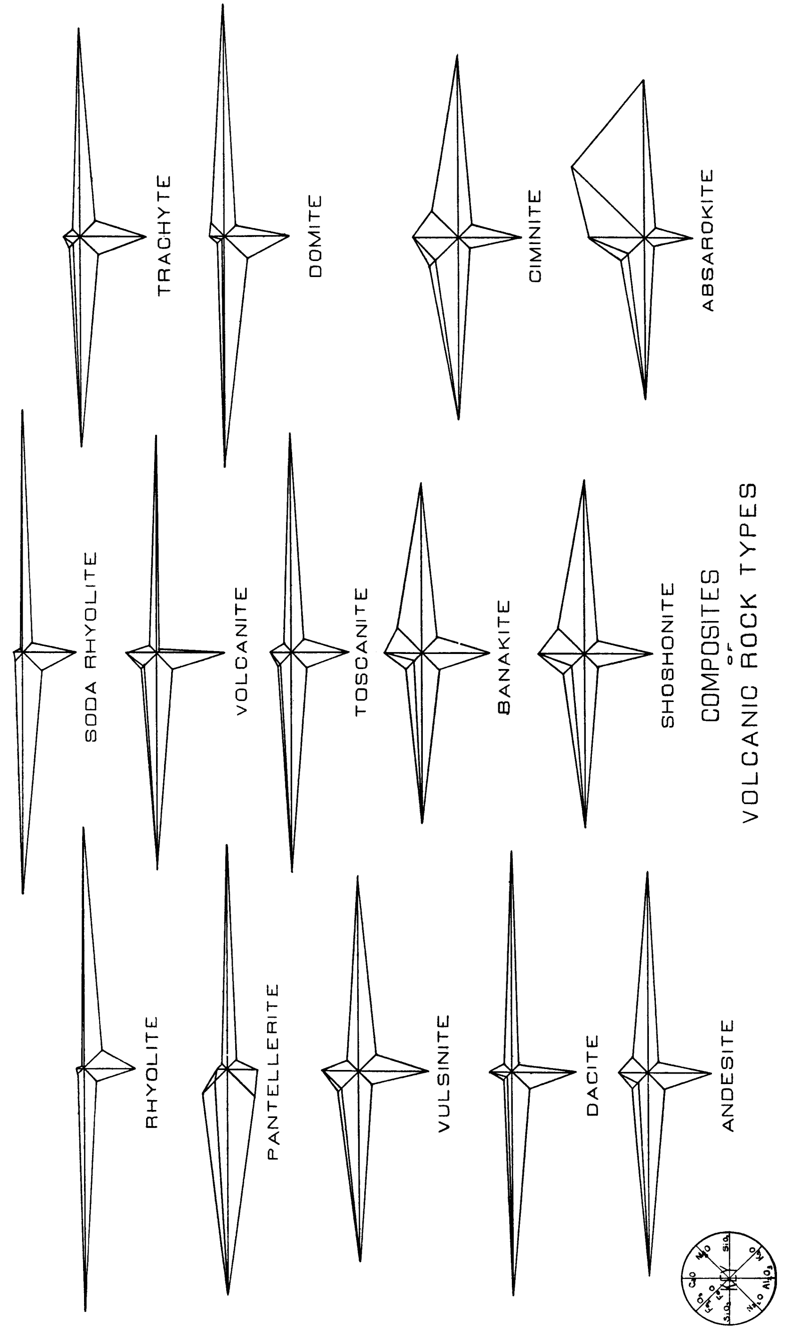




SYENITE-GABBRO SERIES

SERIES COMPOSITES

JOUR. GEOL., VOL. VIII, NO. 1 Plate VII



COMPOSITES OF VOLCANIC ROCK TYPES

In conclusion, I would suggest to all persons publishing analyses of rocks the advisability of printing beneath the figures showing the percentage, composition, the corresponding molecular ratios, and further, that the arrangement of oxides in the analysis be for the sake of uniformity that which has been consistently followed by Rosenbusch, Washington, and some others, and which is here used in the composite tables showing the averaging of analyses for the composite diagrams. The principal deviation from this order which I have observed is an inversion of the order of magnesia and lime or of soda and potash, which can hardly be regarded as essential. If these suggestions be followed, the work of those who examine rock analyses will be materially lightened and the liability to error in transcribing will be lessened.

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University of Wisconsin,
Madison, Wis.

ROCKS WHOSE ANALYSES HAVE BEEN COMBINED TO PRODUCE THE COMPOSITES OF THE GRANITIC-TEXTURED IGNEOUS ROCKS

The greater number of the analyses of these rocks are to be found either in the tables of Rosenbusch's *Elemente der Gesteinslehre*, published in 1898 (abbreviation R), or in Clarke and Hillebrand's *Analyses of Rocks and Analytical Methods*,[1] published in 1897 (abbreviation C and H).

GRANITE [2]

1. Alkali-granite, Drammen, Norway.
2. Alkali-granite, Sandsvar, "
3. Alkali-granite, Pelvoux, Dauphinée, France.
4. Alkali-granite, Hardwick quarry, Quincy, Mass., Am. Jour. Sci. (4), 6, p. 181.
5. Alkali-granite, Montello, Wis., Hobbs and Leith. To be described in a forthcoming bulletin of the Geol. and Nat. Hist. Survey of Wisconsin.
6. Alkali-granite, Waushara Co., Wis., Bull. No. 3, Wis. Geol. and Nat. History Survey, 1898, p. 2.
7. Muscovite-biotite granite, Hautzenberg, Bayerischer Wald, Germany.
8. Muscovite-biotite granite, Katzenfels, Graslitz, Erzgebirge, Bohemia.

[1] Bull. 148, U. S. Geol. Surv.

[2] All the granite analyses with the exception of certain of the alkali granites are selected from Rosenbusch's list, on page 78 of the work cited.

9. Biotite-granite, Bobritzsch, Freiberg, Saxony.
10. Biotite-granite, Barr, Alsace.
11. Biotite-granite, Durbach, Black Forest, Baden.
12. Biotite-granite, Melibocus, Odenwald, Hesse.
13. Hornblende-granite, Mariposa Co., Nevada.
14. Hornblende-granite, Pré de Fauchon, Vosges.
15. Hornblende-granite, Syene, Egypt.
16. Hornblende-granite, ("Rapakiwi granite"), Finland.
17. Augite-granite, Laveline, Vogesen.
18. Augite-granite, Oberbruch, Dollerenthal, Alsace.
19. Augite-granite, Kekequabic Lake, Minn.
20. Augite-granite, Birkrem, Ekersund, Norway.

ALKALI-SYENITE

1. Nordmarkite, Tonsenaas, near Christiania, Norway. R. p. 112.
2. Pulaskite, Fourche Mt., Arkansas. *Ibid.*
3. Umptekite, Umpjaur, Kola Peninsula, Russia. *Ibid.*
4. Laurvikite, Laurvik, Norway. *Ibid.*
5. Sodalite-Syenite, Square Butte, Mont. *Ibid.*

NEPHELENE-SYENITE

1. Nephelene-Syenite, Salem Neck, Mass. Jour. Geol. **8**, p. 803.
2. Nephelene-Syenite, Great Haste Island, Mass. *Ibid.*
3. Litchfieldite, Litchfield, Maine. C. & H., p. 65.
4. Nephelene-Syenite, Red Hill, N. H. C. & H., p. 67.
5. Nephelene-Syenite, Fourche Mt., Arkansas. Igneous Rocks of Ark., p. 88.
6. Lujaurite, Umptek, Kola Peninsula, Russia. R. p. 126.
7. Nephelene-Syenite, Beemerville, N. J. C. & H., p. 80.
8. Basic Nephelene Syenite, Beemerville, N. J. N. Y. Acad. Sci. 11, p. 68.
9. Nephelene-Syenite, Saõ Paolo, Brazil. R. 126.
10. Laurdalite, Lunde, Norway. Zeitsch. f. Kryst. **16**, p. 33.
11. Sodalite-Syenite, Kangersluarsuk, Greenland. R. p. 126.
12. Urtite, Lujaur Urt, Kola Peninsula, Russia. *Ibid.*
13. Leucite-Syenite, Magnet Cove, Ark. *Ibid.*
14. Borolanite, Lake Borolan, Scotland. *Ibid.*

MISSOURITE-IJOLITE SERIES

Missourite

1. Missourite, Shonkin Creek, Highwood Mts., Mont. C. & H. 154.

Shonkinite

1. Shonkinite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 149.
2. Shonkinite, Yogo Peak, Little Belt Mts., Mont. *Ibid.*

3. Shonkinite, Square Butte, Highwood Mts., Mont. R. p. 176.
4. Shonkinite, Monzoni, Tyrol. Zeitsch. d. d. geol. Gesell. **24**, p. 201.
5. Nephelene-Pyroxene-Malignite, Poobah Lake, Canada. R. p. 176.

Theralite

1. Theralite, Gordon's Butte, Crazy Mts., Mont. R. p. 176.
2. Theralite, Martinsdale, Crazy Mts., Mont. *Ibid.*
3. Theralite, Umptek, Kola Peninsula, Russia. *Ibid.*

Essexite

1. Essexite, Salem Neck, Mass., Jour. Geol., 7, p. 57.
2. Essexite, Salem Neck, Mass. R. p. 172.
3. Essexite, Isla de Cabo Fria, Rio de Janeiro, Brazil. *Ibid.*
4. Essexite, Mt. Fairview, Custer Co., Colo. *Ibid.*
5. Essexite, Rongstock, Bohemia. *Ibid.*

Ijolite

1. Ijolite, Iiwaara, Finland. R. 180.
2. Ijolite, Kaljokthal, Umptek, Kola Peninsula, Russia. *Ibid.*

SYENITE-GABBRO SERIES

Syenite

1. Mica-Syenite Frohnau, Black Forest, Baden. R. p. 106.
2. Mica-Hornblende Syenite, Silver Cliff, Colo. C. & H., p. 169.
3. Hornblende-Syenite, Plauenscher Grund, Saxony. R. p. 106.
4. Hornblende-Syenite, Biella, Piedmont. *Ibid.*
5. Monzonite, Monzoni, Tyrol. R. p. 109.
6. Monzonite, Yogo Peak, Mont. C. & H. p. 147.
7. Yogoite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 156.
8. Akerite, Thingshoug, Norway. R. p. 111.

Diorite

1. Tonalite, Adamello, Tyrol. R. p. 140.
2. Banatite, Dognacska, Ranat, Austro-Hungary. *Ibid.*
3. Grano-diorite, near Bangor, Butte Co., Cal. C. & H. p. 204.
4. Diorite, Elk Mts., Colo., C. & H. p. 177.
5. Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
6. Amphibole-Diorite, Electric Peak, Yellowstone National Park C. & H. p. 118.
7. Augite-Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
8. Augite-Diorite, Peach's Neck, Mass. Jour. Geol. 7, p. 60.
9. Diorite, Schwarzenberg, Vogesen. R. p. 140.

Gabbro

1. Anorthosite, Nain, Labrador. Zeitsch. d. d. geol. Gesell. 1884.
2. Orthoclose-Gabbro, Duluth, Minn. Neues Jahrb. f. Min. 1876, p. 117.
3. Gabbro, Northwestern Minn. C. & H. p. 112.
4. Garnetiferous Gabbro, Granite Falls, Minn. C. & H. p. 113.
5. Gabbro, Nahant, Mass. Jour. Geol. **7**, p. 63.
6. Hypersthene-Gabbro, Baltimore, Md. Bull. U. S. Geol. Survey, No. 28, p. 39.
7. Norite, Montrose Point, Hudson River, N. Y. Am. Jour. Sci. (3) **22**, p. 104.
8. Norite, Ivrea, Piedmont. R. p. 151.
9. Forellenstein, Neurode, Silesia. *Ibid.*
10. Forellenstein, Coverack, Cornwall. *Ibid.*

ULTRA-BASIC ROCKS

Pyroxenite

1. Websterite, Webster, N. C. C. & H. p. 92.
2. Bronzite-Diallage Rock, Hebbville, Md. C. & H. p. 84.
3. Hornblende-Hypersthene Rock, Gallatin Co., Mont. C. & H. p. 140.
4. Websterite, Johnny Cake Road, Md. R. p. 165.

Peridotite

1. Mica-Peridotite, Crittenden Co., Ky. C. & H. p. 94.
2. Scyelite, Achavarasdale Moor, Caithness. Quart. Jour. Geol. Soc. **41**, p. 402.
3. Wehrlite, Red Bluff, Gallatin Co., Mont. C. & H. p. 140.
4. Lherzolite, Johnny Cake Road, Baltimore Co., Md. R. 165.
5. Saxonite, Douglas Co., Oregon. C. & H. p. 231.
6. Cortlandtite (Schillerfels) Schriesheim, Odenwald, Hesse. R. p. 165.
7. Bronzite Diallage Peridotite, Howardville, Md. Bull. U. S. Geol. Survey, No. 28, p. 54.
8. Dunite, Dun Mts., New Zealand. R. p. 165.
9. Dunite, Elliott Co., Ky. C. & H. p. 93.

Rare Rock Types

1. Rockallite, Rockall Bank, Atlantic. Geol. Mag. (4) **6**, p. 165. 1899.
2. Basic Nephelene-Syenite, Beemerville, N. J. Trans. N. Y. Acad. Sci. **11**, p. 86.
3. Urtite, Lujaur Urt, Kola Peninsula, Russia. Geol. Fören, Förh, **18**, p. 462. 1896.
4. Ijolite, Iiwaara, Finland, and Umptek, Kola Peninsula, Russia. *Ibid.* **13**, p. 300. 1891.
5. Missourite, Highwood Mts., Mont. Am. Jour. Sci. (4) **2**, p. 315. 1896.
6. Dunite, Elliott Co., Ky. Bull. 38 U. S. Geol. Survey, p. 24. 1887.

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE

	Species of granite					Families of granite-neph.-syenite series			
	Alkali granite (6)	Muscovite-biotite granite (2)	Biotite granite (4)	Hornblende granite (4)	Augite granite (4)	Granite (20)	Alkali syenite (5)	Nepheline-syenite (14)	Composite
SiO_2	74.07 1.226	70.49 1.165	69.43 1.149	69.32 1.147	66.08 1.094	69.88 1.157	60.62 1.004	53.47 .885	61.32 1.015
TiO_2	......	.33	.44	.31	.17	.31	.35	.26	.31
Al_2O_3 ...	13.48 .131	13.77 .135	14.54 .142	13.37 .131	15.81 .155	14.19 .139	19.13 .187	20.87 .204	18.06 .176
Fe_2O_3 ...	1.86 .012	3.69 .024	1.55 .010	1.40 .009	2.12 .013	2.12 .013 3.68	2.57 .017 4.66	4.93 .031 6.20	3.21 .020
FeO	1.29 .018	.02 .000	2.23 .031	2.97 .041	1.30 .018	1.56 .022	2.09 .028	1.27 .018	1.64 .023
MnO.....	......	......	.12	......	......	.02	.10	.07	.06
MgO	.16 .004	.87 .020	.96 .024	1.55 .039	2.17 .050	1.14 .028	.74 .018	.85 .021	.91 .023
CaO.....	.76 .012	1.78 .032	2.94 .053	2.38 .043	2.61 .046	2.09 .037	2.38 .042	2.70 .048	2.39 .043
Na_2O....	4.24 .068	3.82 .062	3.47 .048	2.84 .040	4.36 .061	3.75 .060	6.45 .104	8.26 .133	6.15 .099
K_2O	4.35 .046	4.36 .046	3.91 .042	4.30 .046	4.30 .046	4.24 .045	5.19 .054	5.55 .059	4.99 .053
H_2O	.63	.35	.66	.95	.61	.64	.90	1.32	.95
Others...	......	.18	.05	.50	......	.15	.23	.32	.23
Total ..	100.04	99.66	100.30	99.89	99.53	100.09	100.75	99.87	100.22

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE (*Continued*)

	Families of missourite-ijolite series						Families of syenite-gabbro series			
	Missourite (1)	Shonkinite (5)	Theralite (3)	Essexite (5)	Ijolite (2)	Com-posite	Syenite (8)	Diorite (9)	Gabbro (10)	Com-posite
SiO_2....	46.06 .762	48.80 .808	44.67 .740	47.91 .793	44.71 .740	46.43 .769	58.73 .972	60.23 .997	48.40 .801	55.79 .924
TiO_2....	.73	.59	1.00	1.35	1.41	1.02	.65	.58	.61	.58
Al_2O_3...	10.01 .098	11.13 .108	15.58 .151	17.82 .174	17.46 .170	14.40 .141	16.78 .164	16.14 .158	20.06 .196	17.66 .172
Fe_2O_3...	3.17 .019 } 8.78	3.68 .023 } 9.16	5.28 .033 } 10.13	5.38 .030 } 11.06	5.15 .032 } 8.86	4.53 .022	3.05 .019 } 6.84	2.69 .017 } 7.20	2.99 .019 } 9.39	2.91 .018
FeO.....	5.61 .078	5.48 .076	4.85 .067	5.68 .079	3.71 .052	5.07 .070	3.79 .052	4.51 .063	6.40 .089	4.90 .068
MnO....	......	.07	.11	.02	.20	.08	.14	.02	.04	.07
MgO....	14.74 .364	8.41 .210	6.31 .158	3.26 .081	2.67 .060	7.08 .177	2.77 .069	3.62 .090	6.73 .168	4.37 .109
CaO.....	10.55 .189	12.07 .216	11.05 .197	8.29 .148	11.50 .205	10.69 .191	4.82 .086	6.21 .111	9.38 .168	6.80 .121
Na_2O....	1.31 .021	2.33 .038	5.03 .071	5.45 .088	8.73 .141	4.57 .074	3.29 .053	3.40 .055	2.83 .045	3.17 .051
K_2O....	5.14 .053	4.54 .047	3.10 .033	2.81 .030	1.82 .019	3.48 .036	4.96 .053	1.74 .019	.88 .009	2.53 .026
H_2O....	1.44	1.31	2.36	1.14	.67	1.38	.96	.58	1.84	1.13
Others...	.81	1.80	.31	.86	.85	.93	.46	.22	.02	.23
Total..	99.57	100.09	99.66	99.97	98.88	99.66	100.40	99.94	100.18	100.14

ULTRA-BASIC COMPOSITES

	Pyroxenite (4)	Peridotite (9)
SiO_2	52.58 .871	40.58 .672
TiO_2	.11	.77
Al_2O_3 ...	3.69 .036	3.64 .035
Fe_2O_3 ...	1.90 .012	5.89 .037
FeO	6.50 .090	5.88 .082
MnO.....	.11	.15
MgO	20.86 .521	30.00 .750
CaO	13.23 .236	5.60 .100
Na_2O....	.22 .003	.47 .007
K_2O	.10 .001	.55 .005
H_2O.....	.57	5.32
Others ...	.50	1.64
Total ..	100.37	100.49

RARE ROCK TYPES OF GRANITIC TEXTURE

	1 Rockallite	2 Basic nepheline-syenite	3 Urtite	4 Ijolite	5 Missourite	6 Dunite
SiO_2	73.60 1.218	41.37 .684	45.28 .749	44.71 .740	46.06 .762	29.81 .493
TiO_2	....	....	....	1.41	.73	2.20
Al_2O_3 ...	4.70 .046	16.25 .159	27.37 .267	17.46 .170	10.01 .098	2.01 .019
Fe_2O_3 ...	13.10 .082	16.93 .106	3.53 .022	5.15 .032	3.17 .019	5.16 .032
FeO	....	....	.49 .007	3.71 .052	5.61 .078	4.35 .030
MnO	.93	....	.19	.20	....	.23
MgO	.11 .003	4.57 .113	.33 .009	2.67 .060	14.74 .364	32.41 .810
CaO	.37 .007	12.35 .221	1.22 .022	11.50 .205	10.55 .189	7.69 .137
Na_2O ...	6.96 .112	4.18 .067	17.29 .279	8.73 .141	1.31 .021	.11 .001
K_2O	....	3.98 .042	3.51 .037	1.82 .019	5.14 .053	.20 .002
H_2O	....	.45	.40	.67	1.44	8.92
Others ...	.06	....	....	.85	.81	7.77
Total ..	99.83	100.08	99.61	98.88	99.57	100.86

COMPOSITES OF ROCK TYPES OF RHYOLITIC TEXTURE

	Rhyolite (9)	Soda Rhyolite (6)	Pantellerite (4)	Trachyte (6)	Domite (2)	Volcanite (1)	Dacite (6)	Andesite (7)	Toscanite (10)	Vulsinite (10)	Ciminite[1] (11)	Banakite (4)	Shoshonite (5)	Absarokite (5)
SiO_2 ..	74.12 1.227	74.50 1.233	68.88 1.140	63.97 1.069	67.54 1.118	66.99 1.109	68.25 1.129	62.16 1.029	67.74 1.121	58.97 .976	56.18 .930	52.06 .868	53.19 .886	49.21 .820
TiO_2 ..	......	......	......	.36	......	......	......	.23	......	......	.15	.76	.74	.92
Al_2O_3 .	13.21 .129	13.67 .134	8.01 .078	17.62 .172	16.96 .166	17.56 .172	16.35 .160	16.45 .161	14.77 .144	17.84 .174	16.24 .159	17.66 .173	17.81 .174	12.52 .122
Fe_2O_3 .	1.14 .007	1.22 .008	6.72 .042	2.01 .012	2.97 .018	1.41 .008	1.78 .011	3.27 .020	.60 .004	1.67 .010	2.31 .014	4.66 .029	4.25 .026	4.34 .027
FeO ..	.75 .001	1.71 .024	3.37 .047	1.60 .022	.37 .005	3.39 .047	1.19 .016	2.71 .038	3.15 .044	4.67 .065	6.17 .086	2.20 .030	3.07 .043	4.15 .057
MnO ..	......	......	......	......	.13	......	.01	.02	......	.03	.23	.13	.11	.13
MgO ..	.15 .004	.24 .006	.62 .015	.92 .023	2.08 .051	.93 .023	1.21 .030	2.20 .055	1.06 .024	1.67 .041	3.95 .098	3.33 .083	3.64 .091	10.36 .259
CaO ..	1.11 .020	1.17 .021	1.46 .026	2.32 .041	2.02 .036	4.25 .076	3.03 .054	4.13 .074	2.99 .053	5.02 .090	6.25 .112	5.11 .091	6.25 .111	8.14 .140
Na_2O .	2.67 .037	3.90 .048	6.78 .094	4.62 .064	4.80 .077	3.35 .054	4.31 .060	4.07 .056	3.25 .052	2.76 .045	2.44 .039	4.09 .057	3.43 .047	2.01 .028
K_2O ..	6.06 .063	2.98 .031	3.35 .035	5.59 .059	3.57 .038	.34 .003	2.48 .026	3.45 .037	4.16 .044	5.86 .060	4.44 .047	5.03 .053	3.88 .041	3.74 .040
H_2O ..	.93	.39	.44	1.14	.39	1.53	1.09	1.15	1.92	1.34	1.59	3.74	2.73	3.96
Others.	......	......	......	.03	.60	......	.06	.15	.42	.24	.37	.84	.71	.71
Total	100.05	99.78	99.63	100.18	100.13	99.75	99.76	99.99	100.06	100.07	100.32	99.64	99.81	100.53

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[1] The analyses on which this composite is based are too high in alumina and too low in magnesia. Cf. Washington, Am. Jour. Sci. (4) IX, p. 44, 1900.